

An IP-Based Software System for Real-time, Closed Loop, Multi-Spacecraft Mission Simulations

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Agenda

- Introduction
- Formation Flying Test Bed
- Distributed Space Systems – Distributed Synthesis Environment
- FY02 Prototyping and Demonstration Activities
- FY03 Development and Test Activities
- FY04 and Beyond
- Concluding Remarks



Introduction

● Distributed Space Systems

- Encompasses Formations, Constellations, and Sensor Webs
- Technical Challenges
 - Precise Relative Navigation and Attitude Control
 - Coordinated Control of Space and Ground Assets
 - Inter-spacecraft Ranging and Communications
 - Libration Point and Highly Elliptical Orbit Regimes
 - Coordinated data collection, routing, processing and downlink

● Requirements for DSS Simulation and Modeling

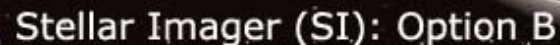
- High Fidelity Dynamics and Reference Frames
- Realistic Modeling of Error Sources
- Distributed Networking and Computing
- Hardware-in-the-Loop Testing





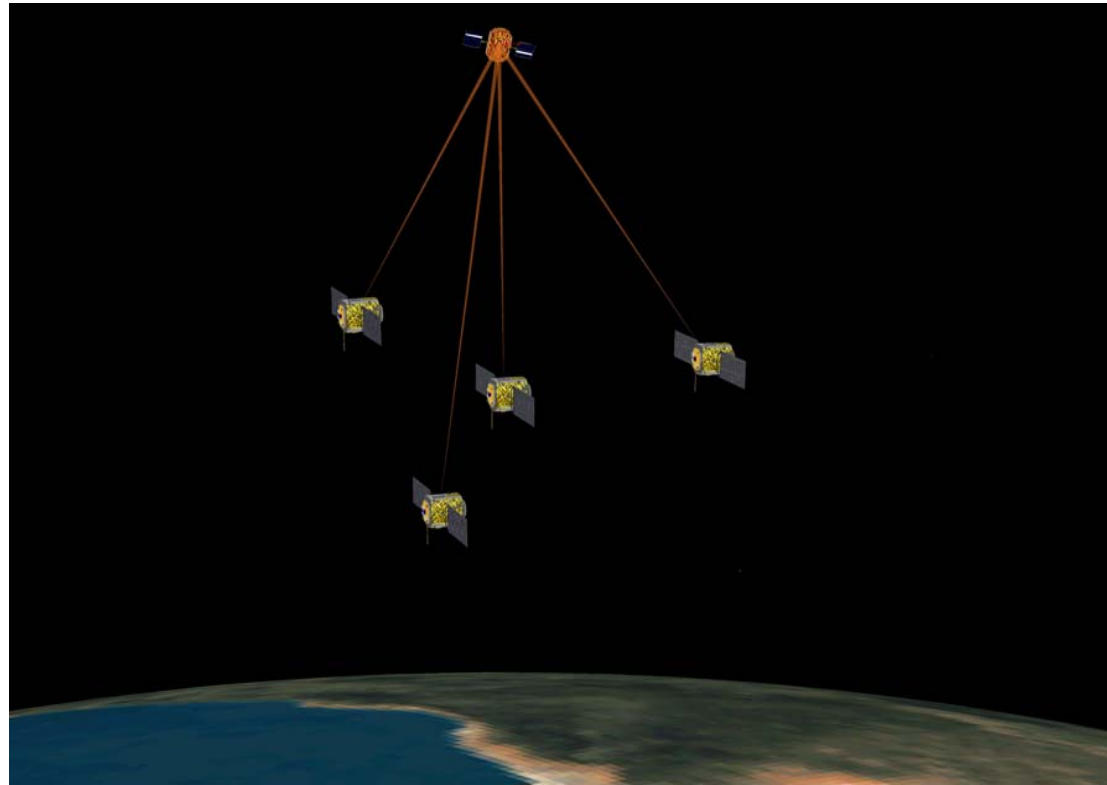
MMS: 4 spacecraft with loose formation control

Increasing GN&C Challenge

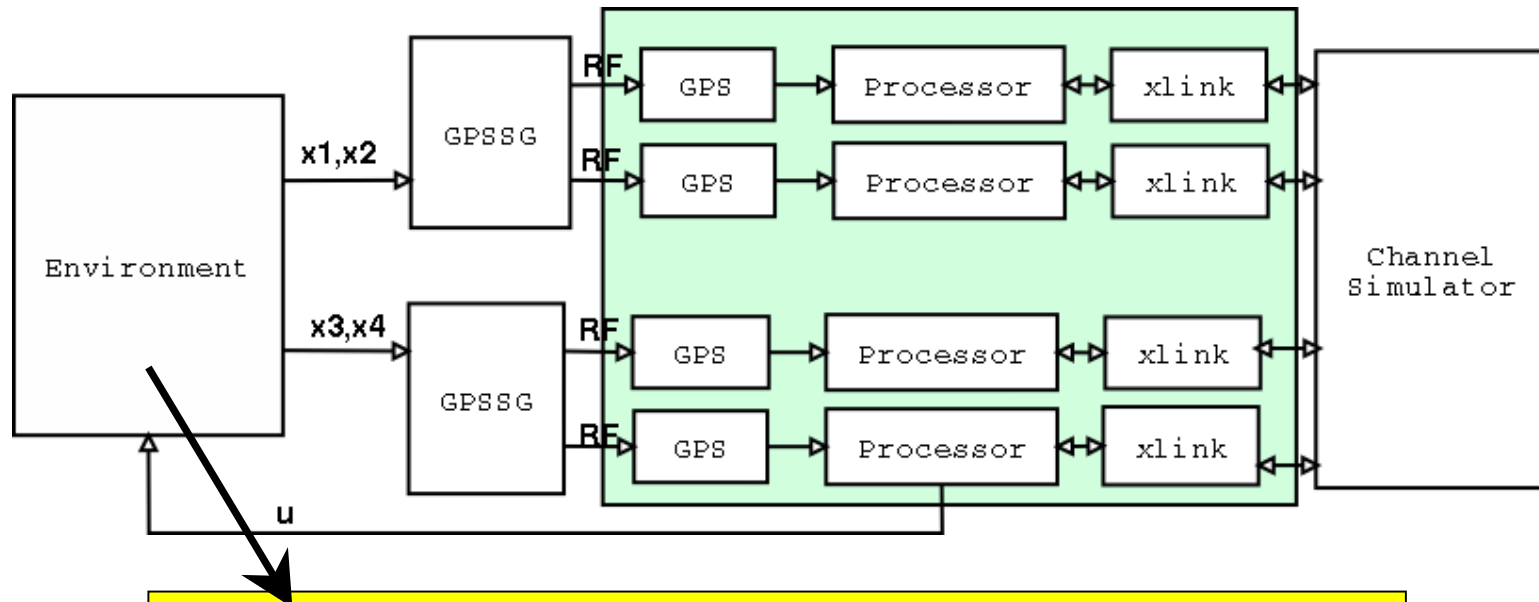


Formation Flying Testbed (FFTB)

- Focus is on GN&C challenges
- Hybrid Dynamic Simulator for:
 - Technology Development
 - Algorithms
 - Hardware
 - Mission Planning and Analysis
 - Simulation and Test
- Hardware-in-the-Loop
 - GPS Receivers
 - Interspacecraft Ranging and Comm
 - Celestial Navigation
- Operational Modes
 - Real-Time
 - Faster-than-Real-Time
 - Slower-than-Real-Time
 - Open-Loop/Closed-Loop Control
- Visualization
 - STK for mission animation
 - Real-time plotting for simulation analysis and monitoring



FFTB Schematic



- Generates spacecraft trajectories, x_i
 - integrates differential equations of motion
 - high fidelity force models
- Accepts control inputs, u (e.g., thrusts)

DSS-DSE

● End-to-End Mission Simulation for Distributed Space Systems

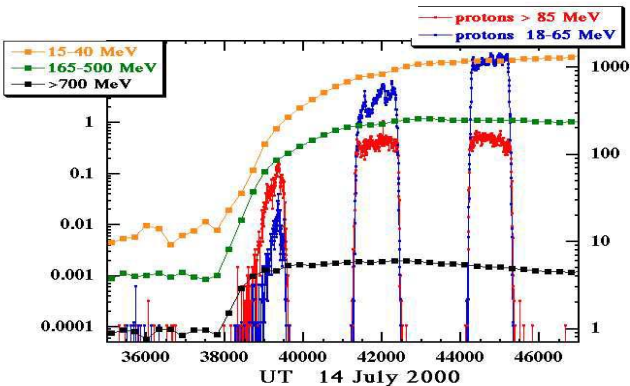
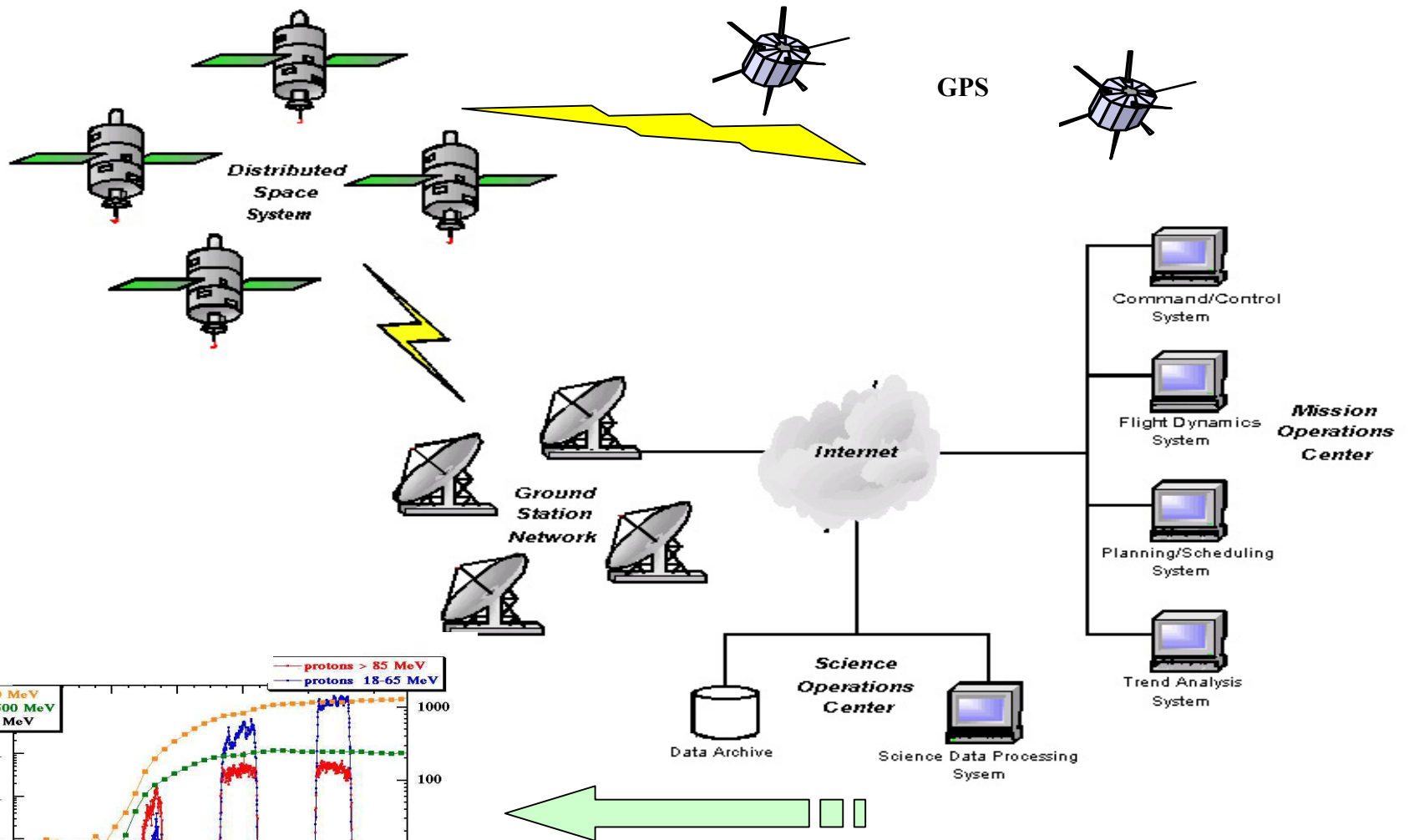
- Integrate existing GSFC test beds for a virtual mission simulation capability
- Science Instrument, Spacecraft Subsystems, Ground Systems, Autonomy all represented in an coordinated, interdependent simulation
- Provides capability to assess effect of mission/system/subsystem level trades on the end product, Science Data

● Envisioned as a tool for DSS missions:

- Mission Design and Planning, including formation & constellation design
- Spacecraft Design
- Feasibility Analysis
- Autonomous Operations



DSS-DSE Concept Diagram



Completed IR&D Activities

- Establish interfaces across GSFC engineering mission resources for simulation and analysis
 - Focus on accessing simulation resources across campus without having to co-locate or modify the direction of resource
 - Simulation resource can support existing responsibilities and activities.
 - Enable resources to tie into DSE and other mission elements for higher level analysis when needs arise
- Support MMS reference mission goals
 - Develop a simulated model of elements supporting, Science Data Simulation, Formation Flying, Space - Ground Communication, Flight Dynamics.
 - Support initial framework for evaluation of ranging mechanisms and further evaluation
 - Provide first steps of an environment that could be used to explore, refine and validate Operations Concepts.



DSE Distributed Test Beds

OFTB (Bldg 23)

4 Spacecraft
C&DH Systems

Alarms

Science

Nav

Space

Ground

MDP

Ground
System

MDP

Flight
Dynamics
(OD)

OFTB (Bldg 23)

AutoFDS (Offsite)

SITB (Bldg 28)

Science
Instruments

Instrument
Sim.

CNE

FFTB (Bldg 11)

GPS
Simulator

GPS
Xmit

Dsim

Orbit/
Attitude

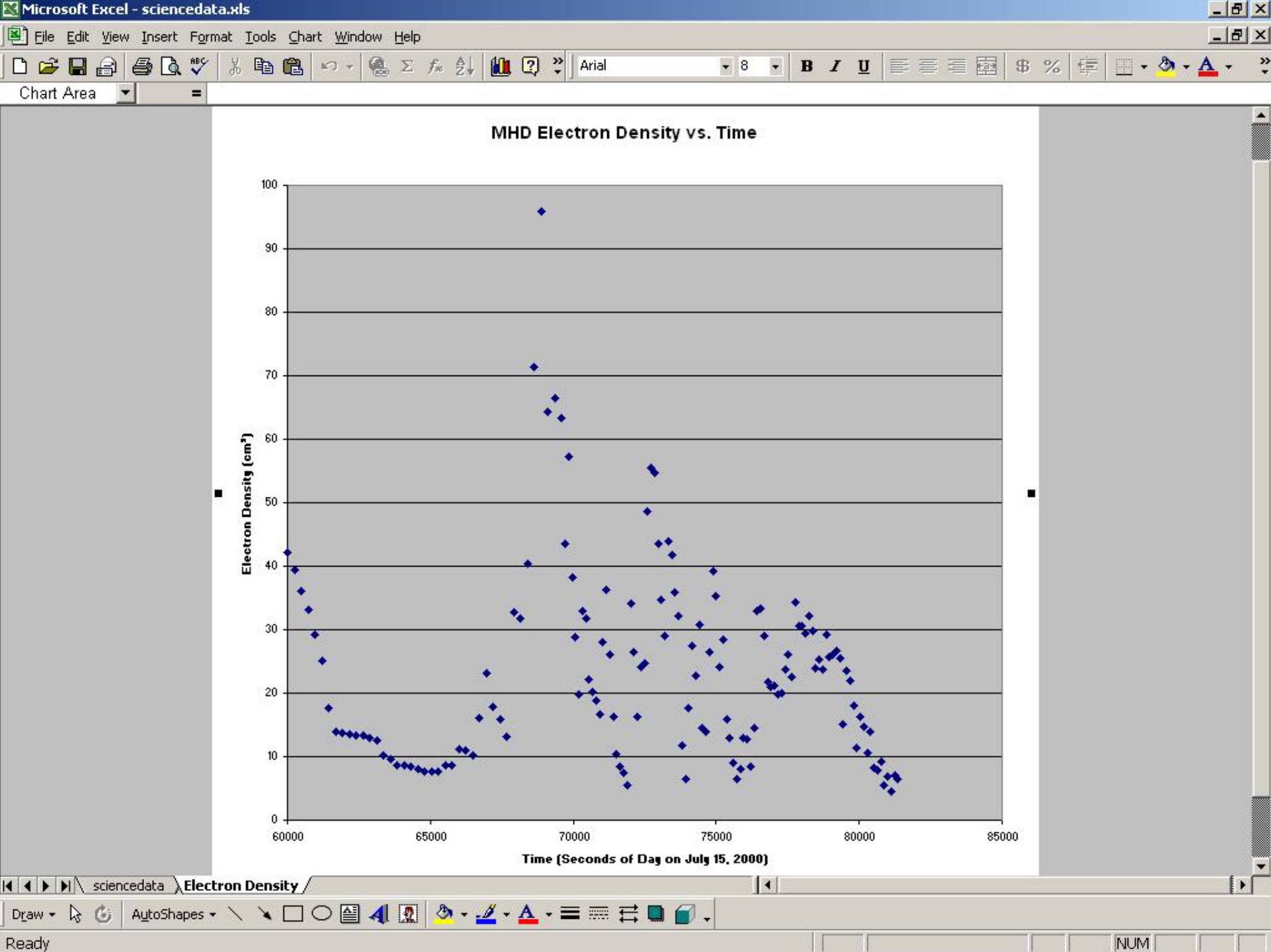
PIVOT
GPS Rcvr

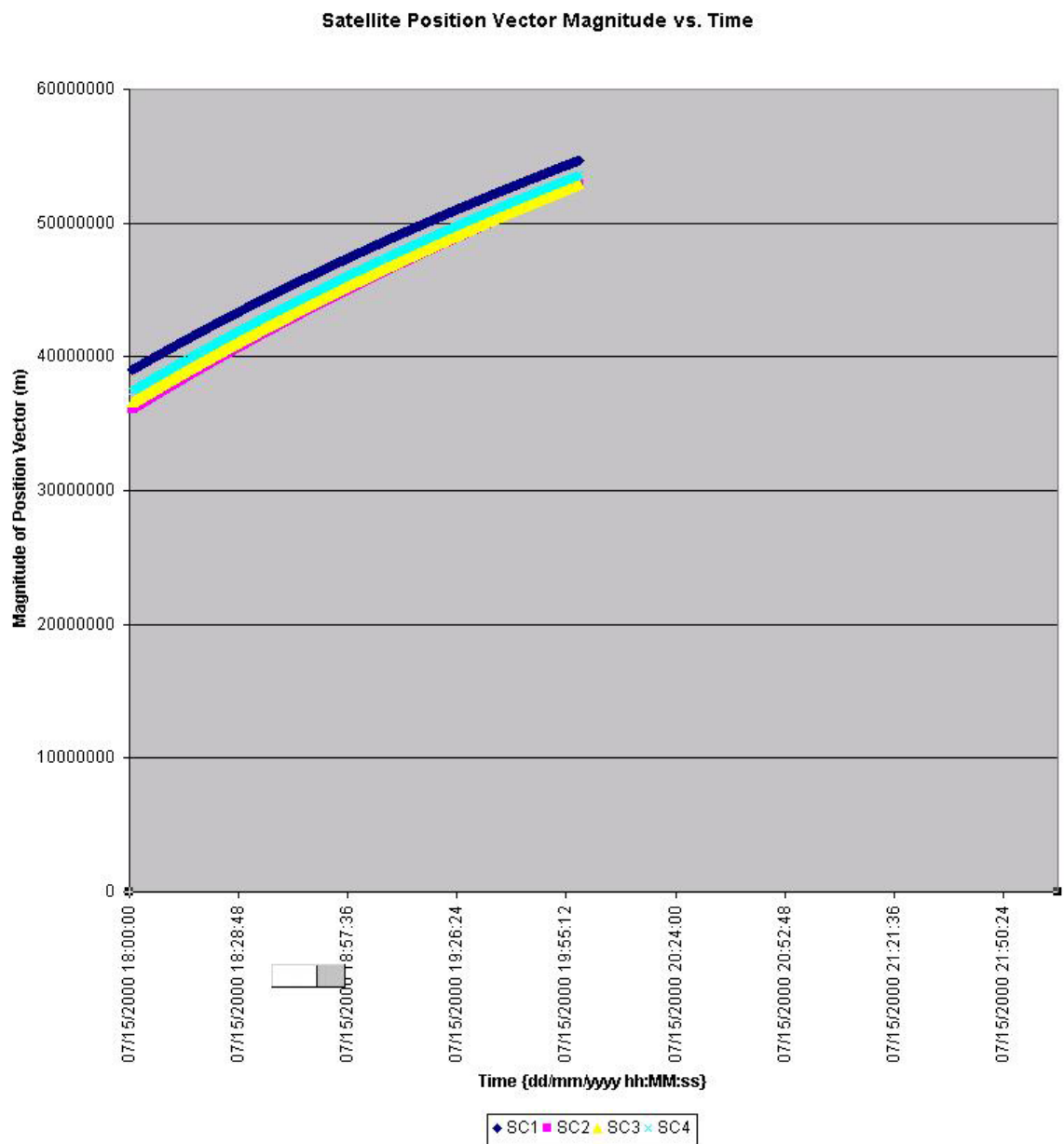
STK

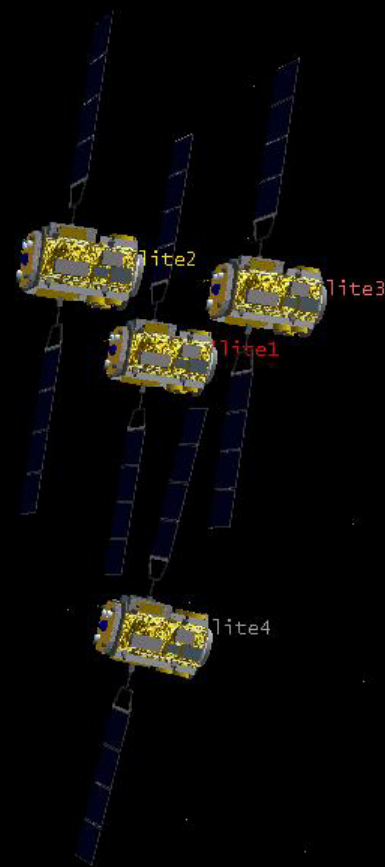
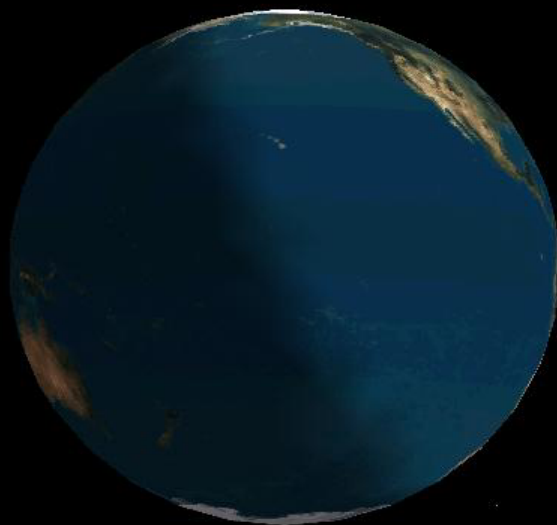
Data
Visualization

FFTB (Bldg 11)









Earth Inertial Axes

15 Jul 2000 17:01:48.00

Time Step: 1.00 sec



Development and Test Activities

● Infrastructure

- Redesign and develop FFTB software as distributed, middleware-enabled, object-oriented simulation system
- Integrate FFTB software with telemetry simulator (SIMMS) for more robust DSS simulation capability
- Design and develop GUI for easy-to-use controller of the FFTB software
- Implement Cross-Link Channel Simulator for Inter-spacecraft Ranging and Communications HWIL Testing Support
- Address Timing (e.g., latency, synchronization ...) and Security Issues

● Demonstrations

- Real-Time, Closed-Loop Control
- Relative Navigation and Control
- Inter-spacecraft Ranging
- Target Mission Simulation and Test Support: GPM, MMS, TechSat-21



Concluding Remarks

- The FFTB and the DSS-DSE exploit Internet technology to support end-to-end mission simulations:
 - GN&C
 - Instruments
 - Communication Networks
 - Ground Systems
 - Automation and Autonomy
- Successes to Date
 - Successfully integrated simulation and test resources across GSFC and across country for meaningful end-to-end simulation
 - Enabling meaningful dataflow of simulated science, telemetry across GSFC networks for trade studies
 - Defines framework for adding other elements and change of specifications through an ICD

